

## The Rapid Response Radiation Survey (R3S) Mission Using the HiSat Conformal Satellite Architecture

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### ABSTRACT

The Rapid Response Radiation Survey (R3S) experiment, designed as a quick turnaround mission to make radiation measurements in Low Earth Orbit (LEO), will fly as a hosted payload in partnership with NovaWurks using their Hyper-integrated Satlet (HiSat) architecture. The need for the mission arises as the Nowcast of Atmospheric Ionization Radiation for Aviation Safety (NAIRAS) model moves from a research effort into an operational radiation assessment tool. Currently, airline professionals are the second largest demographic of radiation workers and to date their radiation exposure is undocumented in the USA. The NAIRAS model seeks to fill this information gap. The data collected by R3S, in addition to the complementary data from a NASA Langley Research Center (LaRC) atmospheric balloon mission entitled Radiation Dosimetry Experiment (RaD-X), will validate exposure prediction capabilities of NAIRAS.

The R3S mission collects total dose and radiation spectrum measurements using a Teledyne  $\mu$ Dosimeter and a Liulin-6SA2 LED spectrometer. These two radiation sensors provide a cross correlated radiometric measurement in combination with the Honeywell HMR2300 Smart Digital Magnetometer. The magnetometer assesses the Earth's magnetic field in the LEO environment and allows radiation dose to be mapped as a function of the Earth's magnetic shielding. R3S is also unique in that the radiation sensors will be exposed on the outer surface of the spacecraft, possibly making this the first measurements of the LEO radiation environment with bare sensors.

Viability of R3S as an extremely fast turnaround mission is due, in part, to the nature of the robust, well-defined interfaces of the conformal satellite HiSat Architecture. The HiSat architecture, which was developed with the support of the Defense Advanced Research Projects Agency's (DARPA's) Phoenix Program, enabled the R3S system to advance from the first concept to delivery of preliminary design review (PDR) level documents in 29 calendar days. The architecture allows for interface complexities between the specific devices and the satellite bus to be resolved in a standardized interface control document (ICD). The ICD provided a readymade framework to interface to the modular satellite bus. This modularity allowed for approximately 90% of the R3S system to be designed and fabricated in two months without constraint of the hosting satellite's development cycle.

This paper discusses the development of the R3S experiment as made possible by use of the HiSat architecture. The system design and operational modes of the experiment are described, as well as the experiment interfaces to the HiSat satellite via the user defined adapter (UDA) provided by NovaWurks. This paper outlines the steps taken by the project to execute the R3S mission in the 4 months of design, build, and test. Additionally portrayed is the ground work done at LaRC to posture the organization for a fast response and the process by which the opportunity was identified as aligning with key strategic goals. Finally, a description of the engineering process is provided, including the use of facilitated rapid/concurrent engineering sessions, the associated documentation, and the review process employed.

## AUTHOR'S NOTE

The views, opinions, and/or findings contained in this article/presentation are those of the author(s)/presenter(s) and should not be interpreted as representing the official views or policies of the Department of Defense or the U.S. Government."

## INTRODUCTION

Significant efforts have been made in the scientific community to understand the science behind space radiation and its effects on both biological and atmospheric systems. The Rapid Radiation Response Survey (R3S) mission was designed to collect experimental data that will help scientists and engineers better understand how to shield against space radiation. R3S will collect on-orbit radiometric and magnetic measurements with a Liulin-6SA2 radiation spectrometer, a Teledyne  $\mu$ Dosimeter Total Ionizing Dose (TID) detector, and a Honeywell HMR2300 magnetometer, which are shown in figure 1. R3S is manifested to fly as a hosted payload on the DARPA eXCITE mission, which will demonstrate the NovaWorks developed HISat conformal satellite architecture. The R3S hosted payload will interface to the main satellite bus with a robust and standardized User Defined Adapter (UDA). In this paper we will discuss the science behind the R3S mission, the HISat Architecture, and use of a UDA to obtain science measurements, and the engineering details of the R3S mission. We will describe how the Interface control document (ICD) defined UDA allowed for asynchronous development. We will discuss the process used to advance the R3S mission concept from first thought to a funded effort, with reviewed CDR documents, in 29 calendar days. Finally, we will show how a concurrent engineering capability allowed the systems engineering to progress to approximately 50% of the complete engineering design in under a week including an appropriate level of review.



**Figure 1: The R3S instrument consists of three commercially available sensors; The Liulin-6SA2 Linear Energy Transfer (LET) spectrometer, a Teledyne  $\mu$ Dosimeter TID detector, and a Honeywell HMR2300 magnetometer**

## SCIENCE MOTIVATION

Space is bathed in a sea of high-energy charged particles that penetrate deeply within both Earth's atmosphere and spacecraft. This radiation environment is of interest to not only satellite and spacecraft communities, but also the aviation community. The deeply penetrating nature of energetic particle radiation can negatively impact both aviation systems and the health of both passengers and aircrew<sup>1,2</sup>. There are two sources of energetic particle radiation which impact spaceflight and air flight. The first are known as galactic cosmic rays (GCR). GCR are a low intensity, high energy background of fully ionized nuclei which originate outside the solar system. The second source of space radiation is the sun and will be classified under the name solar particle events (SPE). SPE are periodic eruptions from the sun, in which particles (dominantly protons) are accelerated to high energies with fluences that can be many orders of magnitude larger than the GCR background. While much more intense than GCR, SPE may last for hours to days, but do not typically have the very high energy component that is always present in the GCR.

Space radiation presents a problem for all long-term operations in space and is a significant component to the risk for satellite operations and human health<sup>3,4,5,6,7</sup>. Additionally, commercial aircrew are classified as radiation workers by the International Commission on Radiological Protection<sup>5</sup> and the United States National Council on Radiation Protection and Measurement (NCRP). A 2006 study reported that aircrews were the highest exposed group of the radiation workers monitored during their study<sup>4</sup>. Recent epidemiological study by Grajewski et al.<sup>9</sup> also found a correlation between flight attendant radiation exposure and increased risk of miscarriage.

In order to assess the risk due to radiation for human health and electronic systems, a vast amount of knowledge and understanding is required. For instance a detailed knowledge of the radiation environment; the physics of radiation interactions with materials, electronic systems, and human bodies; and the conversion of exposure to risk are all required to both accurately design spacecraft, aircraft, subsystems thereof, and missions. To understand the effects of radiation on designs, models are used to assess the impact of the radiation. Radiation transport models are used to understand how the radiation environment

changes as it encounters and traverses different materials. Radiation transport models typically output physical exposure quantities such as flux and dose (energy deposited per unit mass), and may be able to output biologically important quantities such as dose equivalent or effective dose. These exposure quantities can then be assessed by models to determine various inherent risks, such as the risk of single event upsets (SEU) for electronics or the risk of exposure induced death (REID) for humans.

To gain confidence in models and understand model reliability, models must be correlated to experiments to quantify the uncertainties quantified in the model. The Rapid Response Radiation Survey (R3S) is an experiment conceived to provide this confidence by quickly leveraging an opportunity to deliver experimental data on the space radiation environment for use in quantifying radiation transport model uncertainty. R3S will measure the radiation dose of the minimally altered space radiation environment by exposing two dosimeters to the space environment without radiation shielding. In addition, R3S will measure the magnetic field in orbit. This measurement will allow for calculation of the geomagnetic shielding provided by Earth's magnetic field in orbit.

## **NARAIS**

The primary customer of the R3S data will be the Nowcast of Atmospheric Ionizing Radiation for Aviation Safety (NAIRAS) model<sup>9,10,11</sup>. NAIRAS is a real-time, global, physics-based model used to assess radiation exposure to commercial aircrews and passengers. The model is fully physics-based with no free parameters used to adjust model results into agreement with measurements. It includes the contribution from both GCR and SPE, along with the dynamical response of the geomagnetic field to external forces. The output provides a global map of the radiation environment throughout Earth's atmosphere, allowing for a complete flight-path dependent radiation exposure calculation in real-time. NAIRAS consists of many different component models. Among others, there are models for characterizing the GCR environment and SPE environment, models for nuclear and atomic interactions, models for the composition of the Earth's atmosphere, models for the geomagnetic field, a radiation transport model. Each of these models provides a critical component to the assessment of a given radiation exposure calculation.

NAIRAS was developed to enhance decision support for assessing the safety of flight paths in real-time. The model's results can be used for aircrew career planning and to assist in developing policies and procedures for mitigating aircrew and public radiation exposure. To

transition into operational use, NAIRAS must be validated against experimental data. The International Commission on Radiation Units and Measurement (ICRU) recommends total uncertainty in radiation assessments to not exceed a limit of 30% for aircraft cosmic radiation exposure at flight altitudes with annual exposures above a threshold of 1 mSv in ambient dose equivalent<sup>12</sup>. In addition to the ICRU requirement to transition to operations, NAIRAS has adopted an As Low As Reasonably Achievable (ALARA) view of uncertainty reduction beyond the ICRU requirement. This translates into a systematic attempt to understand not only the overall uncertainty of NAIRAS, but the contribution of different component model uncertainty to the overall uncertainty.

Upon data correlation with NAIRAS, R3S will contribute to a better understanding of the component uncertainty in the model by removing the radiation transport model contribution from the experimental data. As the R3S dosimeters will be exposed to the space radiation environment without material shielding, there will be a minimal contribution of the uncertainty due to transport through shielding materials. In addition, the uncertainty will be able to be mapped as a function of the geomagnetic field, which will allow for an assessment of the variation in exposure uncertainty with geomagnetic field strength. These quantities, while of special interest to NAIRAS, will also be of interest to the greater radiation shielding community for validation and modeling development purposes.

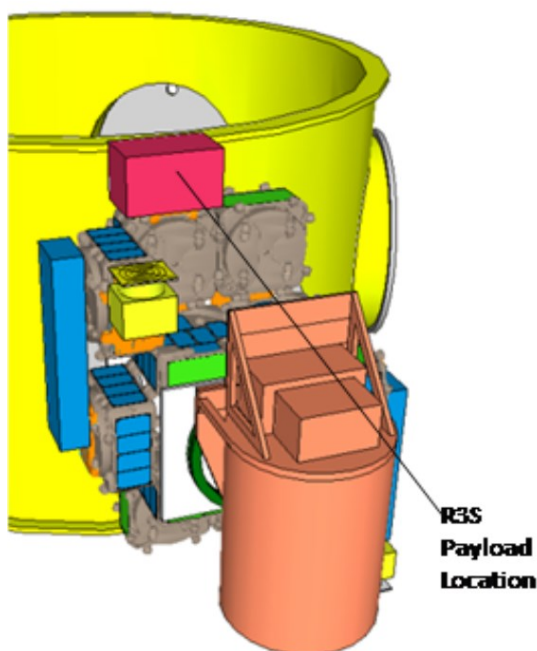
## **HISAT ARCHITECTURE**

NovaWurks has developed a new class of small satellites (satlets)<sup>13,14</sup>. The satlet design demonstrates the concepts of "cellularization" and "morphological reconstruction". Each Satlet constitutes a complete standalone system that contains requisite individual subsystems (e.g. propulsion/thruster) that can be aggregated together in spatially co-located entities to increase performance with increased numbers.

NovaWurks' Hyper-Integrated Satlet (HISat) hyper-integrates functionality into components, leverages performance aggregation, utilizes COTS parts where possible, and is designed towards a mass-producible satlet. Whereas spacecraft cellularization has historically been about connectivity of information, HISat goes beyond data connectivity and also aggregates via mechanical attachment and integral unified control of power, thermal, sensing, and actuation.

The distributed architecture of aggregated satlets called PACs (Package of aggregated cells) allows for better utilization of the resources available from each HISat to

carry out various mission scenarios. For example, if an attitude control system requires a certain amount of momentum, each HISat in the aggregation can provide a small amount of torque to distribute the load required from the specific attitude maneuver. A management system inherent in the design of each HISat allows for the aggregation to perform in all subsystems similar to a monolithic satellite, with the benefits of distributed architecture. The distributed architecture also creates a more resilient spacecraft to the harsh space environment while providing increased reliability and availability to the payload. If a single HISat fails to operate nominally, the spacecraft/PAC enters a non-critical, still-functional state as opposed to a catastrophic failure.



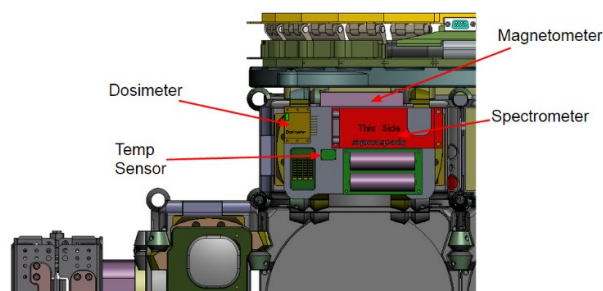
**Figure 2: eXCITE configuration with R3S location**

A low-earth orbit mission called eXCITE (Experimental Cellular Integration technology) has been proposed to demonstrate the ability of the HISat to hyper-integrate functionality through cellular architecture.

The eXCITE spacecraft, consists of twelve HISats in a PAC and various payloads including R3S. The subsystem interfaces between HISat PACs and payloads is the User Defined Adapter (UDA) which provides a mechanical, electrical, thermal and structural bridge.

As one of the three payloads hosted on eXCITE, R3S is mounted onto the UDA, subsequently mounted to one of the available sides on the PAC. In order to properly characterize the radiation environment, the sensor and UDA location has been optimally chosen according to

requirements for field of view, temperature and minimal electromagnetic interference.



**Figure 3: Detailed view of R3S integrated with eXCITE PAC**

The R3S segment of the mission will contribute to the overall demonstration of the HISat and PACs effectiveness as well as its ability to integrate with a scientific payload.

## SYSTEM DESIGN AND OPERATIONL MODES

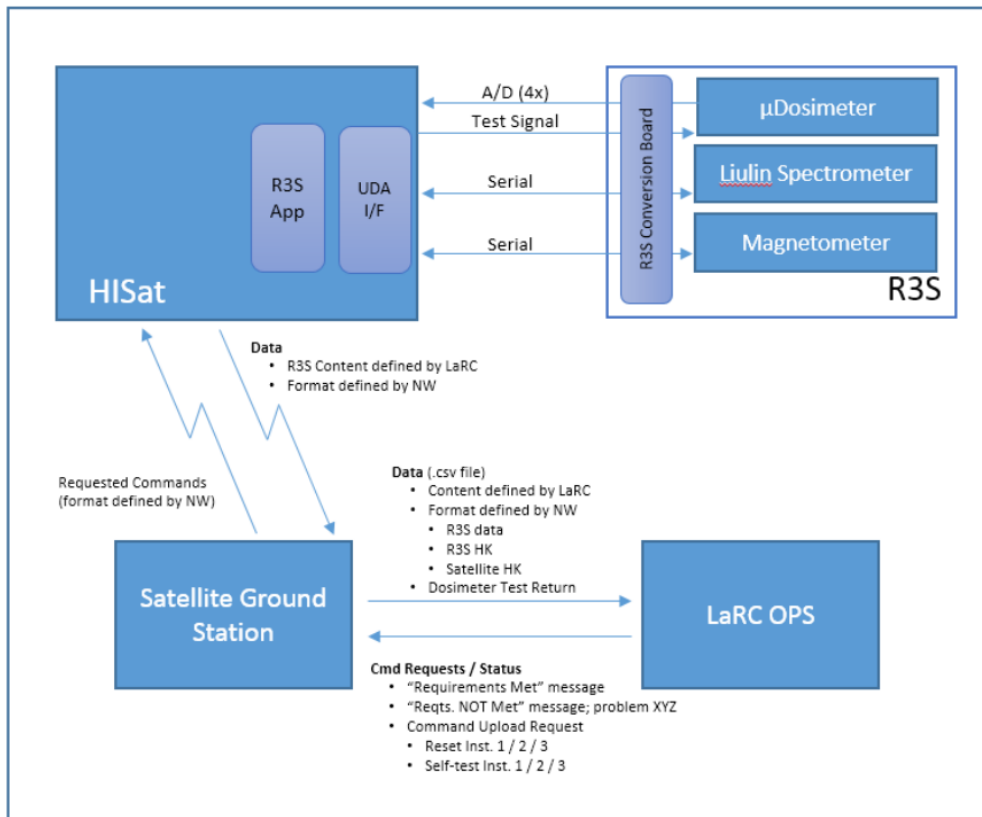
### *Principle Experiment Requirements*

The goal of the R3S mission is to collect LEO total ionizing dose, radiation spectrum, and magnetic field measurements for the NAIRAS model that will reduce the uncertainty in the NAIRAS model. As mentioned previously data collected will help radiation modelers better understand how well the models currently in use compare to experimental measurement and help assess uncertainties and understand from where these uncertainties are arise.

### *System Description and function*

The goal of the R3S mission is to collect Low Earth Orbit (LEO) total ionizing dose, radiation spectrum, and magnetic field measurements that will reduce the uncertainty in the NAIRAS model. As mentioned previously, data collected will help radiation scientist better understand how well their models correlate to experimental measurements and help locate and assess uncertainties.

To meet these goals, it was necessary to devise a mission architecture to deliver the three sensors (a dosimeter, a spectrometer, and a magnetometer) into orbit while minimizing the impact of the hosting spacecraft on the measurements. Per the HISat architecture, a four part system is used to meet this end consisting of the sensors, a UDA, the hosting HiSat PAC and a mission operations plan that governs the software operating.



**Table 1: R3S data-take profile**

Time	Activity
$T_0$	Start Data Take
$T_0 + 00:00:01$	Power Cycle all R3S devices
$T_0 + 00:00:05$	Self-test $\mu$ Dosimeter
$T_0 + 00:00:10$	Power Cycle all R3S devices
$T_0 + 00:00:15$	Self-test Liulin spectrometer
$T_0 + 00:00:20$	Self-test magnetometer
$T_0 + 00:01:30$	Sample #1
$T_0 + 00:02:30$	Sample #2
$T_0 + 00:02:30$	Sample #3
	$\vdots$
$T_0 + 23:28:30$	Sample #1439
$T_0 + 23:29:30$	Sample #1410
$T_0 + 23:29:40$	Self-test all R3S devices
$T_0 + 23:30:00$	<b>Data Take Complete</b>

Part of the efficiency of the R3S is its simple operational concept. The interface between LaRC and the instrument while on orbit, as well as the operations between the R3S team members at LaRC and the eXCITE ground station, will consist solely of email communications. Air-to-ground communication is

provided as a feature of the PAC. The R3S instruments connects to and communicates with the spacecraft PAC through the Used Defined Adapter (UDA).

All communication with the R3S is controlled by an App that runs on the HISat, so there is no flight software on board the R3S instrument. Instead the App will be developed and onboard the HISat's Android OS to operate R3S data-take at the appropriate point in the mission.

The timeline for the R3S mission is driven by the host-spacecraft operations schedule. Once the R3S operation window opens, the measurements are captured and organized into a "data-take" operation.

A single R3S data-take consists of  $23\frac{1}{2}$  contiguous hours of data, with readings taken from all three R3S instruments once per minute for the Liulin Linear Energy Transfer (LET) Spectrometer and HMR2300 magnetometer, and once every 6 seconds for the Teledyne uDosimeter. Each data-take, described in Table-1, operation 1) begins with power cycling then 2) performing a self-test of each instrument, 3) executing the data take, and finally 4) concludes with another self-test. When a full data-take operation is completed, the data is converted and formatted to Level1 engineering values in a .cvs file. These Level1 engineering values

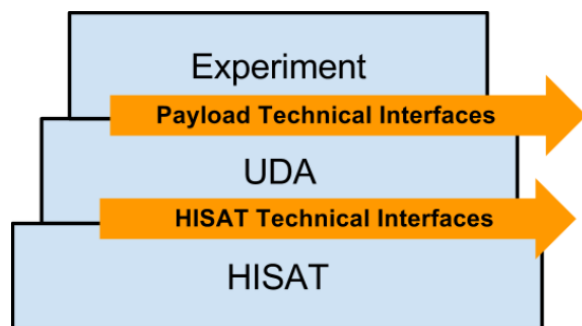


(i.e. Engineering Units) will then be emailed in a file to R3S personnel at LaRC.

Once the data file has been received by LaRC, R3S personnel will verify that the data meets the science requirements. Once the verification process is complete, LaRC will email the Ground Station a message informing them that either a.) the data file received met the requirements, or b.) the data file did NOT meet requirements, and will provide an explanation of the nonconformance. If a non-conformance occurs, further debugging may be done with more detailed commands.

### EXPERIMENT INTERFACE TO HISAT VIA THE USER DEFINED ADAPTER (UDA)

The implementation of R3S onto the NovaWurks PAC is possible given two documents; the ICD and the safety document. The ICD is a document submitted to NASA describing the interfaces between the R3S instruments, and the UDA and the interfaces between the UDA and the HISat PAC as depicted in figure 4. The safety document is provided by NASA to NovaWurks and supplies all the relevant information required to assess the risk the R3S hosted payload poses to the mission of including the R3S hosted payload. Because R3S is a hosted payload “going along for the ride” the safety document enables the project to obtain a waiver to fly with the mission. This documentation construction significantly simplifies interactions and review structure of the engineering effort by allowing a high degree of asynchronous development on various components of the experiment.



**Figure 4: The UDA provides a customizable link between the experiment and the standard HISat attachment interface.**

#### *Electrical*

The UDA hosts a custom printed circuit board that consolidates the input/output electrical interfaces and power to the R3S sensors. Power converters are and serial interfaces devices are supplied to break out the 5V and 14V power, the 5V TTL serial lines, and RS485

channels required by the sensors. To reliably operate the uDosimeter, circuits were added to interface board that capture the continually updating the analog values of the four analog output lines. These analog outputs report the accumulated dose as an incremented four separate 0-5V signal similar to the way an odometer reports miles traveled. The interface board generates a test-signal to validate the health of the uDosimeter. The test signal, a truncated saw-tooth wave, trips silicon detector charge thresholds and can simulate a sensed dose rate of up to 10milliRads/second.

#### *Thermal*

R3S also takes advantage of the thermal control UDA option, which ties the R3S UDA into the PAC’s fluid thermal management system. Capable of driving up to 10W of heat transfer capability at a 5K temperature delta, the UDA will drive the R3S instrument to its thermal control point of 18C +/- 2deg C for the duration of the data-take. The tight thermal control will hold the R3S radiation sensors within the relatively narrow data quality limits of 12C to 25C, in turn, enhancing the radiation measurement quality and the cross correlation of the radiation sensors. The temperature sensor used to verify the sensor thermal state will also be used to control a survival heater and it’s supply battery as a way of avoiding excursions below the -20C survival limit of the Liulin while the PAC is not powered and during testing.

#### *Mechanical*

Mechanically the UDA ties to the structure of the PAC with a quick disconnect universal mate. As an element of a conformal satellite, the universal mount allows the heated sensor, heater/backup battery, and interface electronics package to be mounted appropriately on the PAC to maximize scientific benefit.

#### *Safety*

The safety document was generated by the R3S instrument team at Langley and includes information in three general categories; system parts and materials, vibration testing, and thermal-vacuum testing (TAC). Because the R3S instruments are low power (~1W for the whole system) the EMI/EMC tests will be waived and a functional compliance test will be conducted and documented.

The safety document is populated with part data, test reports from the vibration, functional compliance, and TVAC testing. R3S project will report the results of workmanship level vibration testing and standard contamination measures such as the CVCM (collected volatile condensable materials) and NVR (non-volatile residue) tests results.

## SENSOR CHARACTERIZATION

R3S was designed to use two dosimeters to quantify the ionizing radiation environment of space. Two different dosimeters, each with their own specific response to the radiation environment, will be used in order to constrain the systematic uncertainties associated with the sensors. Both dosimeters are silicon-based, and therefore should measure the same physical dose and dose rate. Practically, however, differences in the sensors will lead to slightly different measurements. These differences can be quantified and corrected for through calibration. The R3S calibration plan will expose both sensors simultaneously to a known radiation source of energy and type consistent with the space radiation environment. It is important that both the energy and type of radiation accurately represent the space radiation environment in order to properly correlate the instruments for the flight environment.

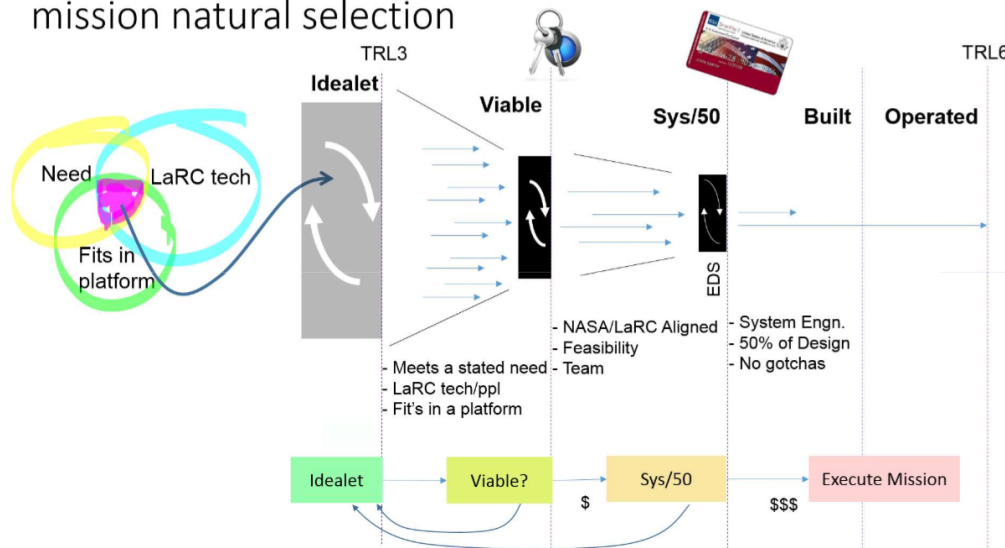
The dosimeters are mounted facing out on the UDA, and the UDA is positioned externally on the PAC to increase the uninhibited solid angle exposure of the sensors to the space environment. To compensate the Steradian obstruction from the spacecraft experienced by the detectors, an obstructed mass analysis will be performed as an element of post processing. The obstructing mass analysis is accomplished by a ray trace analysis followed by a radiation report. The ray trace assess the mass contribution along each of the up to 10,000 rays as they penetrate a solid geometry CAD model of the entire spacecraft. The mass contributions along each of the rays is processed and generates an input to OLTARIS (On- Line Tool for the Assessment of Radiation in Space) model, which delivers the correction factors for the science measurements that will be provided for incorporation into the radiation models

No calibration is necessary for/with/on the Honeywell HMR2300 magnetometer. The magnetometer contains a set/reset routine that calibrates the coordinate sensors and provides automated temperature drift corrections. The sensors microcontroller logs housekeeping data to report on the sensors external serial data interface and to stores necessary setup variables on an onboard EEPROM (Electrically Erasable Programmable Read-Only Memory) for best performance.

The magnetometer is positioned to receive minimum exposure to the spacecraft magnetic fields as it detects the daily variations on the order of 300 micro-Gauss. Ideally an environmentally sensing magnetometer would be placed at the end of a boom outside the magnetic fields characteristic specific to the spacecraft. Given the constraints of the flight opportunities it was deemed suitable to mount the self-calibrating

Honeywell HMR2300 magnetometer, which has a sensitive <70 micro-Gauss, directly on the outward facing region of the PAC. A survey of the characteristic fields generated by various pack electrical configuration be produced to compensate for spacecraft generated fields. The survey results will be used as a baseline against which the LEO magnetic environment will be calibrated to the sensor.

## mission natural selection



### PROCESS USED TO DEVELOP R3S: THE LAB77 MODEL

R3S is a product of NASA Langley Research Center's Lab77, which is a small satellite utilization team geared to develop and execute feasible mission concepts using small satellites. The development of a capability that uses small sats to further the NASA mission is seen by Langley management as enabling technology maturation and demonstration of sensor systems as they further the Nation's initiatives. To this end a process model has been developed and is being exercised that combines the conventional innovation funnel techniques stage-gate engineering processes.

The process, shown in figure 5, is focused around the design of a mission to advance a singular core technology from TRL 3 to 6<sup>15</sup>. A candidate concept for Lab77 is said to be an "Idealet" when the lab team agrees that the mission concept a) is desirable (aligns to a road map need), b) has a team able and willing to advance the concept, and c) is compatible with an available small sat platform. If the concept meets these three criteria, it is listed as an Idealet and is then "tested for viability." Similar to an Idealet, a concept is "Viable" if a) it is determined to be aligned with center and agency goals, b) engineering detail is developed to level that provides confidence that the concept is substantive and practical, and c) if the platform compatibility criteria is still satisfied. From here, Viable missions likely to receive support enter an "Engineering Design Studio (EDS) Study" to conduct a "Sys/50" analysis that will bring the system engineering of the entire mission concept up to 50% of the design complete (approximately half-way between PDR and CDR).

**Figure 5: The process used by Lab77 combines an innovation-funnel and stage-gate engineering processes to grow concepts to executed missions while allowing for graceful mission failure.**

Up until the point of engaging in a Sys/50 EDS Study, the level of investment in the Viable mission is little more than a hallway conversations and the effort required document the concept. At the start of an EDS Study, a low level of formal investment is needed to support the "pre-work" development of the mission core engineering and organizational products in preparation for the one week "EDS Session." Once the Sys/50 analysis is complete the fully half-designed mission is considered for funding if no significant technical roadblocks were found in the EDS Study. The products developed from a Sys/50 analysis, listed in Table 2, are provided as decision support material in addition to the comments of senior engineers who participated in the EDS Session as reviewers. Once supported, a mission goes on to the build phase and, if successfully built and tested, it is delivered for flight. Presently Lab77 is targeting a cadence of four delivered flight-ready experiments per year developed with a 4 month EDS Study followed by a three to nine month build phase.

This process is continuously being developed and refined to enhance the use of small satellites in furthering NASA and LaRC objectives. This model has shown its strength and efficiency in the development process. For example, R3S was developed using this process model, and was able to move from first concept to Sys/50 complete (CDR documents delivered) in 29 calendar days. At the time of delivering R3S, it is estimated that the team will have only spent a total of four months of concerted effort to complete the experiment build. Launch failure related complications



saw to it that the four months of effort were non-contiguous as build schedules shift various reasons. None the less the R3S mission was developed from concept to flight hardware delivery in record time.

**Table 2: The products of a Sys/50 analysis provides ample data for a senior executive to make a funding decision on an affordable high-risk mission with low risk to the organization portfolio.**

Systems Engineering	Design Engineering	Programmatic
<ul style="list-style-type: none"> <li>- Con-ops</li> <li>- Architecture</li> <li>- Interface definition</li> <li>- Con-ops system diagram</li> </ul>	<ul style="list-style-type: none"> <li>- requirements</li> <li>- Mechanical model</li> <li>- Electrical block diagram with parts list</li> <li>- Power budget</li> <li>- Cabling estimate</li> <li>- Thermal analysis</li> <li>- Structural analysis</li> <li>- Software architecture</li> <li>- Sensor system</li> <li>- Testing and evaluation plan</li> </ul>	<ul style="list-style-type: none"> <li>- Cost &amp; Schedule</li> <li>- Review comments from senior engineers</li> </ul>

It is worth noting that R3S is not the first to attempt flight using this model. The end goal of the model is to build a team that delivers a capability of using small sats to further a larger mission. Thus, it is imperative to acknowledge that activities that do not complete the process to flight delivery are still seen as valued and successful learning experiences as they are returned to idealet stage for future advancement.

## FACILITATED CONCURRENT ENGINEERING SESSIONS

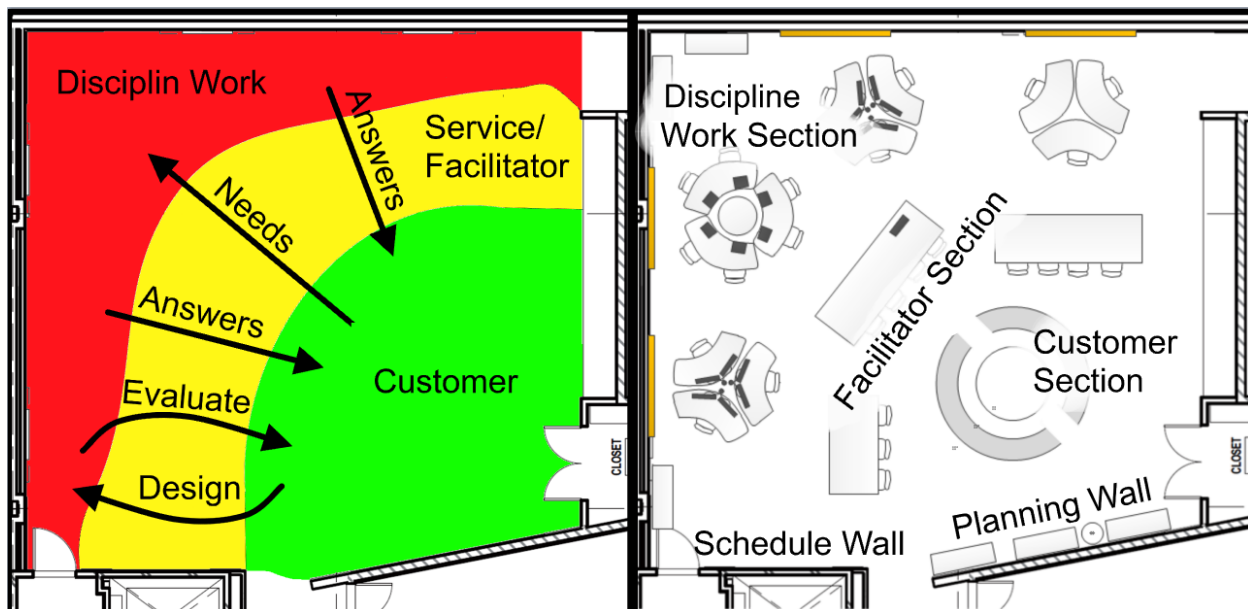
As previously mentioned one of the contributing factors to the development of the R3S mission was the utilization of the Engineering Design Studio (EDS). The EDS is a staffed collaborative engineering environment involving the use of an EDS-facility, facilitation team, and process. When properly harnessed the result is an extremely efficient design environment resulting in extraordinary leaps forward

with respect to a project's design schedule and technical rigor.

The EDS facility is composed of three general sections all housed within the same room; a customer section, facilitation section, and discipline work section. The customer section is designed to house various round-table discussions to enable the customers' needs to be understood. The facilitation section is where the customer and EDS staff guide the session to ensure the customers' needs are met, and the discipline section is where the engineering work is completed per the customers' request. Figure 6 below illustrates where the EDS sections are with respect one another and how the general flow of information moves throughout the room.

Along with the three sections of the room the EDS facility takes advantage of state of the art technology in the form of four high definition projectors each capable of displaying up to 4 simultaneous video or computer displays, 3 video teleconference cameras capable of panning across all dimensions of the room, twelve independent computer inputs spread across each of the facility sections, 16 wireless microphones, a state of the art sound system, dry erase and pin-up boards lining the walls, and a touch screen panel enabling single point control of the entire facility. Figure 7 below is a picture if the EDS facility in use.

The EDS team is comprised of the facilitating EDS core team, customer, and discipline leads. The EDS core team is responsible for the coordination of events both prior & post session, facilitation of the session, and operation of the facility. The customers are typically Principal Investigators looking to enhance the knowledge of their particular field, a Project Manager looking to overcome a particular project specific milestone, or a combination of the two. The discipline leads are hand chosen experts in their fields who are either already working the project in question, or chosen to step in and work in a session where their specific expertise is required.



**Figure 6: The Engineering Design Studio accommodates large teams and naturally adds structure to complex workflows.**

The EDS process involves four phases; planning, pre-work, session, and closeout. The planning phase involves a customer request, determination of whether or not a session is appropriate or feasible, and an initial planning meeting. The outputs of the planning phase are a preliminary list of session goals, dates, agenda, technical deliverables, and a team roster. The pre-work

from the deliverables list, a list of yet to be completed session tasks, and a list of follow on work (i.e. information gaps) that need to be explored outside the confines of the EDS process. The last phase is closeout and involves post session work, report out, and a customer feedback meeting. The outputs of the closeout phase are lists of lessons learned, action items yet to be completed, a 5x5 risk identification matrix, a OneNote™ notebook documenting all efforts, and a completed customer feedback survey.



**Figure 7: The open plan form, with state of the art acoustics, enables team to flow effectively between group and breakout co**

phase is comprised of project team training and/or orientation, pre-work, and a pre-work meeting. The outputs of the pre-work phase are a prioritized technical deliverables list, technical deliverables assignee (i.e. point of contact) list, completed pre-work, and solidified updates to the session goals, agenda, & dates as necessary. The session phase is where the actual concurrent engineering takes place and involves session preparation, the session itself, and an optional residual wrap-up session if required. The outputs of the session phase are completion of the predetermined deliverables

The goals of the EDS study specific to the R3S mission involved the development of an Interface Capabilities Document (ICD) and Safety document. These goals were identified during round-table discussions in the customer section which later carried over to the facilitation section. From there the customers' needs were pushed out to the discipline section in where a

feedback loop was established between the customer and discipline leads which was guided by the EDS core team. In addition, the telecommunication capability of the facility allowed conversations between the Langley R3S team and remotely located vendors to ensue in a timely manner thus enabling the concurrent engineering to seamlessly progress forward. The result was the rapid and thorough completion of both the ICD and Safety documents enabling the R3S team to quickly move on to the next steps in their development process.

## CONCLUSION

The Rapid Response Radiation Survey is manifested to fly as a hosted payload on the DARPA eXCITE mission. The instrument is expected to be deployed on orbit with approximately four months of concerted effort by the joint NovaWurks/NASA Langley team. The work is estimated to be spread over the space of more than 6 months, culminating with the delivery of an instrument that will improve our knowledge of radiation exposure for aviation safety. The use of innovation funneling made it possible to identify a suitable experiment for the opportunity. A concurrent engineering capability allowed the systems engineering to progress to approximately 50% of the complete engineering design in under a week all while maintaining an appropriate level of review. The use of a conformal satellite architecture allowed for the accelerated development of a hosted payload capable of making needed scientific measurements. The robust and standardized interface of the NovaWurks UDA and HISat architecture allowed for asynchronous development as the integrated team worked to an ICD defined hardware interface. The effectiveness of the conformal spacecraft architecture is expected to be demonstrated as the R3S payload collects data to enhance the NARAIS model and improve our knowledge about radiation exposure in our skies.

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